ION Advanced Solvent CO_2 Capture Pilot Project

DE-FE0013303

NETL 2016 CO2 Capture Technology Conference

August 9, 2016

Presented by: Erik Meuleman, PhD

Outline

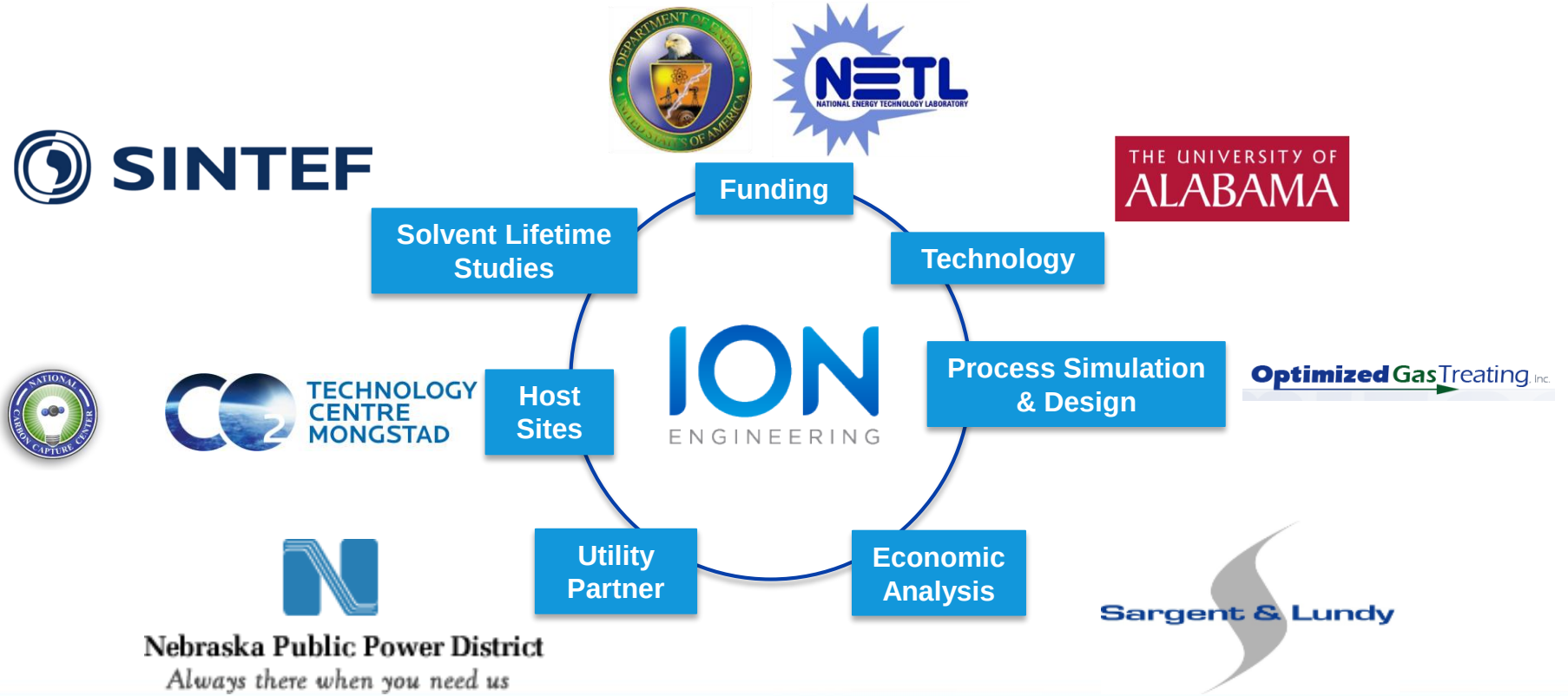
- ION Project
- ION Campaign at NCCC (0.6 MWe) in 2015
- ION 2016 Techno-Economic Analysis
- Outlook of ION campaign at TCM (12 MWe) in 2016/17

ION Advanced Solvent CO_2 Capture Pilot Project

Project #: DE-FE0013303

- 45 Month Project (Oct 2013 – June 2017)
- 0.6 MWe Test Campaign at National Carbon Capture Center (NCCC)
- 12 MWe Test Campaign at Technology Centre Mongstad (TCM)
- $25.2M Total Project Funding
  - $16.4M DOE
  - $8.9M ION and Partners (35% cost share)

Project Participants & Roles



Budget Period 2 – ION campaign at NCCC

January 1, 2015 – March 31, 2016

Task #	Task Description	Key Objectives	Progress
1	**Project Management**	• Coordinate and plan project activities • Maintain Budget, Schedule, Task Reviews, and Costs • On-Boarding of Personnel	• Regular meetings with project team, NCCC, and DOE • ION Personnel needed for PSTU Testing have been on-boarded
5	**Host Site Preparation**	• Modifications necessary to PSTU • ION Solvent Delivery • Installation of mobile lab	• Complete June 2015
6	**Operational Preparation & Shakedown**	• Develop Procedures for Operations • Develop Test Plans • Pilot System Commissioning & Shakedown Testing	• Complete June 2015
7	**ION Solvent Testing**	• Solvent Testing on PSTU at NCCC	• PSTU Test Campaign 06/22/15 – 08/05/16
8	**Data Acquisition, Storage & Analysis**	• Installation of Data Acquisition Systems • Data Acquisition & Analysis • Solvent lifetime testing with SINTEF	• Data analysis of PSTU complete • SINTEF Solvent Lifetime Testing On-going
9	**Decommissioning**	• Removal of ION related equipment	• Completed August 2015
10	**Final Systems Analysis**	• Final Techno-Economic Analysis • Final EH&S Risk Assessment	• Final NCCC Campaign Report, Final EH&S Risk Assessment Delivered to DOE • Final Techno-Economic Analysis to be Delivered Aug 2016

Milestones for BP-2: ION campaign at NCCC

#	Milestone	Target Completion Date	Completion Date
1	PSTU Modifications Complete	5/15/2015	6/15/2015
2	ION Proprietary Solvent Delivery	5/29/2015	4/29/2015
3	Pre-Startup Safety Review	5/29/2015	6/16/2015
4	Pilot System Shakedown Complete	6/12/2015	6/20/2015
5	ION Solvent Testing Complete	9/30/2015	8/10/2015
6	Final TEA and EH&S Risk Assessment	2/26/2016 (EH&S) 8/6/2016 (TEA)	2/26/2016 (EH&S)
7	Solvent Performance & Stability Assessment	2/26/2016	2/26/2016
8	Decommission & Dismantle	11/27/2015	8/31/2015
9	Final DOE Report & Presentation	3/31/2016	4/1/2016

BP-3 – Task Overview – Campaign at TCM

October 1, 2015 – June 30, 2017

Task #	Task Description	Key Objectives	Progress
1	**Project Management**	• Coordinate and plan project activities • Maintain Budget, Schedule, Task Reviews, and Costs • On-Boarding of Personnel	• Regular meetings with project team, TCM, and DOE
11	**TCM Host Site Preparation**	• Modifications necessary to TCM • ION Solvent Procurement & Delivery	• Solvent will be delivered at end of September
12	**TCM Operations Preparation & Shakedown**	• Develop Procedures for Operations • Develop Test Plans • Pilot System Commissioning & Shakedown Testing	• ION has completed first draft of test plan to be reviewed with TCM • Analytical methods to be discussed in detail with TCM at visit in August
13	**TCM Solvent Testing**	• Solvent testing at TCM	• Scheduled to begin October 2016
14	**TCM Data Acquisition, Storage & Analysis**	• Installation of Data Acquisition Systems • Data Acquisition & Analysis	• Data Acquisition to be discussed in detail with TCM and TCM IT-subcontractor at visit in August
15	**TCM Final Systems Analysis**	• 2017 Techno-Economic Analysis • 2017 EH&S Risk Assessment	• N/A

BP2 & BP3 Project Schedule

ION Engineering CO2 Capture Slipstream Project Schedule		Budget Period 2															Budget Period 3														
		2015												2016			2016												2016		
		Q1			Q2			Q3			Q4			Q5			Q1			Q2			Q3			Q4			Q5		
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Task	**Description**																														
1	Project Management																														
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6	Operational Preparation & Shakedown																														
7	ION Solvent Testing																														
8	Data Acquisition, Storage & Analysis																														
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12	TCM Ops Preparation & Shakedown																														
13	TCM Solvent Testing																														
14	TCM Data Acquisition, Storage & Analysis																														
15	TCM Final Systems Analysis																														

ION CAMPAIGN AT NATIONAL CARBON CAPTURE CENTER

Operational Considerations

- Pilot Slipstream Test Unit (PSTU) at NCCC plant was designed for MEA
- ION's liquid absorption system behaves similar but different

- Operational priorities:
  - 1st Priority – Maintain Process & Water Balances
  - 2nd Priority – Flue Gas treating to meet DOE goal of 90%+ removal of CO_2
  - 3rd Priority – Operational Stability & Efficiency (to validate ProTreat® model)

Modifications to NCCC PSTU

- Set-up of on-site mobile wet chemistry laboratory
- Installation of a chiller to control flue gas temperature entering the absorber
- Installation of thermal insulation around the lean-rich cross exchanger

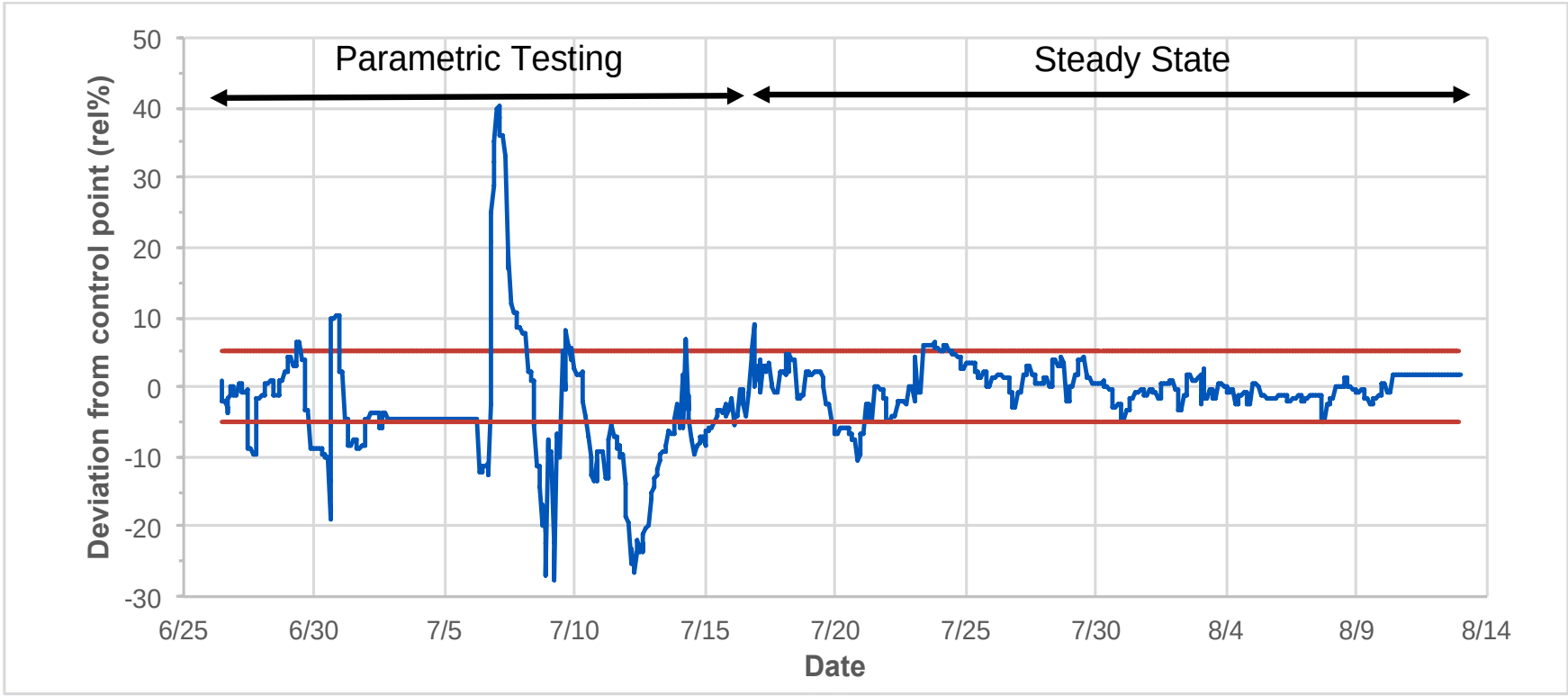
Parametric Testing

- Confirm Mechanisms of Process Control
  - Water Balance / Top Absorber Temperature
    - Solvent Flow Rate
    - Lean Solvent Loading
      - Regeneration Pressure
      - Reboiler Steam Rate
    - Demonstrated Control of Temperature Profile in the Absorber
  - Solvent Performance
    - Regeneration Pressure
    - Thermosiphon – Reboil ratio
    - Packing Height
    - L/G

NCCC DATA WORKUP & RESULTS

Water Balance & System Inventory
Solvent Loss
ProTreat Model Validation
Solvent Performance

Water Balance

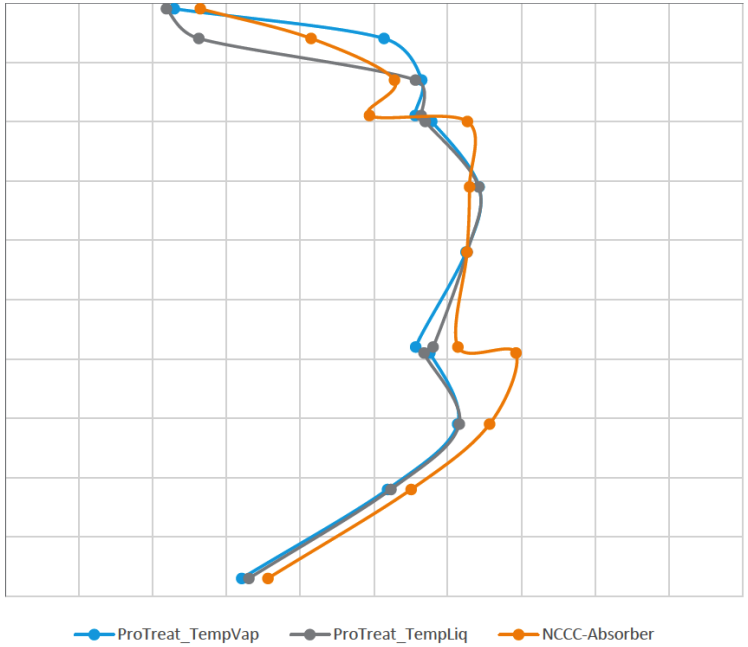


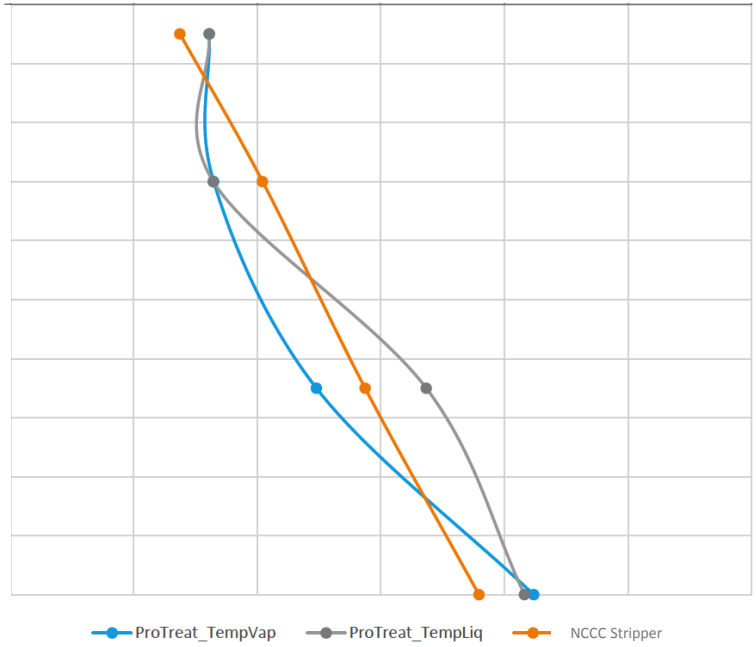
Integrity Check of Level Balance

Measured through Solvent Additions

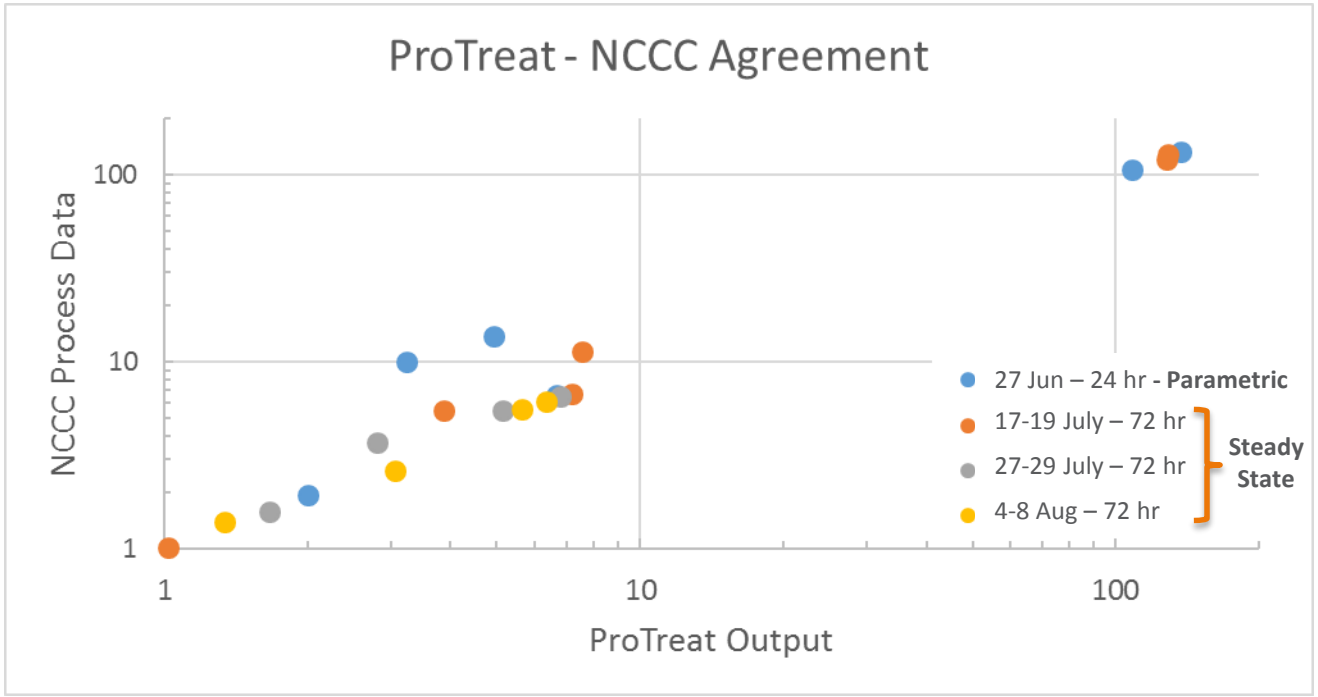
- Addition of solvent was used for inventory evaluation
- Solvent addition was visible in level and concentration data
- Solvent mass & component mass computed from Levels and Analytical data
- Compared against mass and concentration of known addition to determine accuracy

ProTreat® Simulations – Model Validation (GHGT-13)



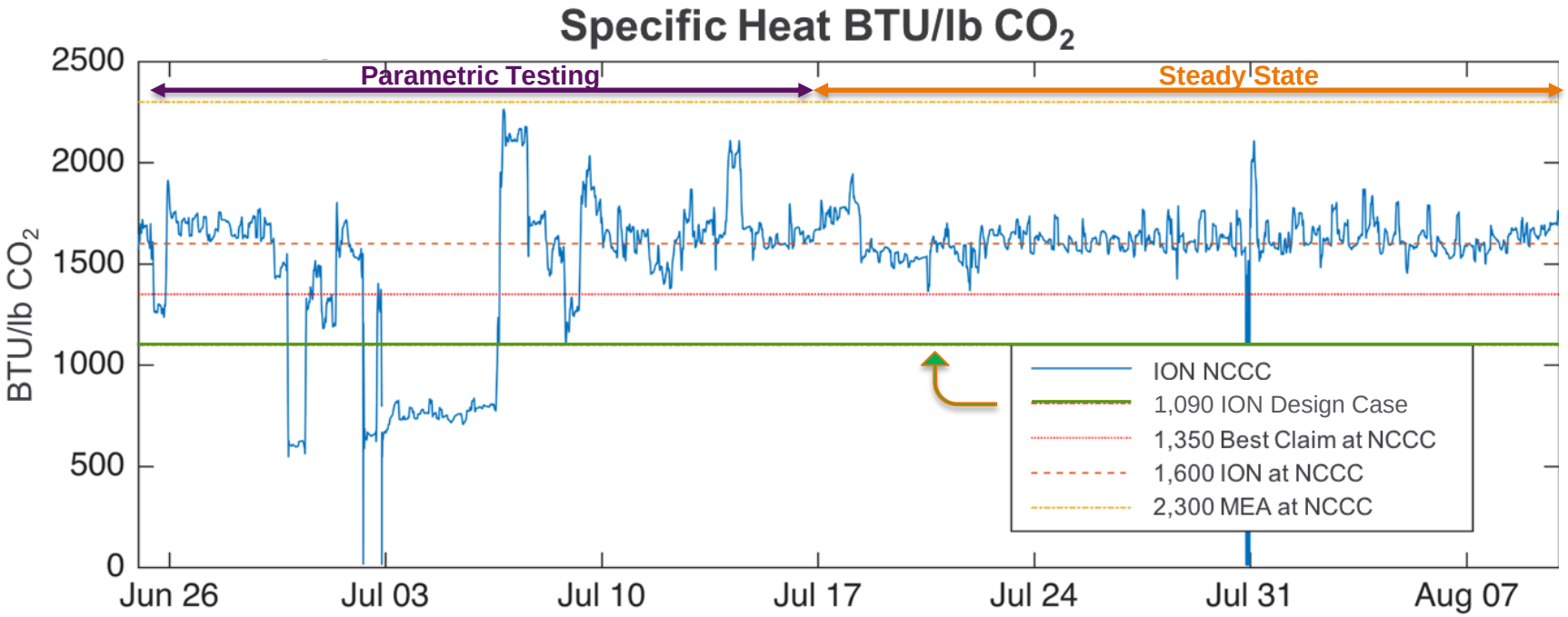


ProTreat® Model Validation

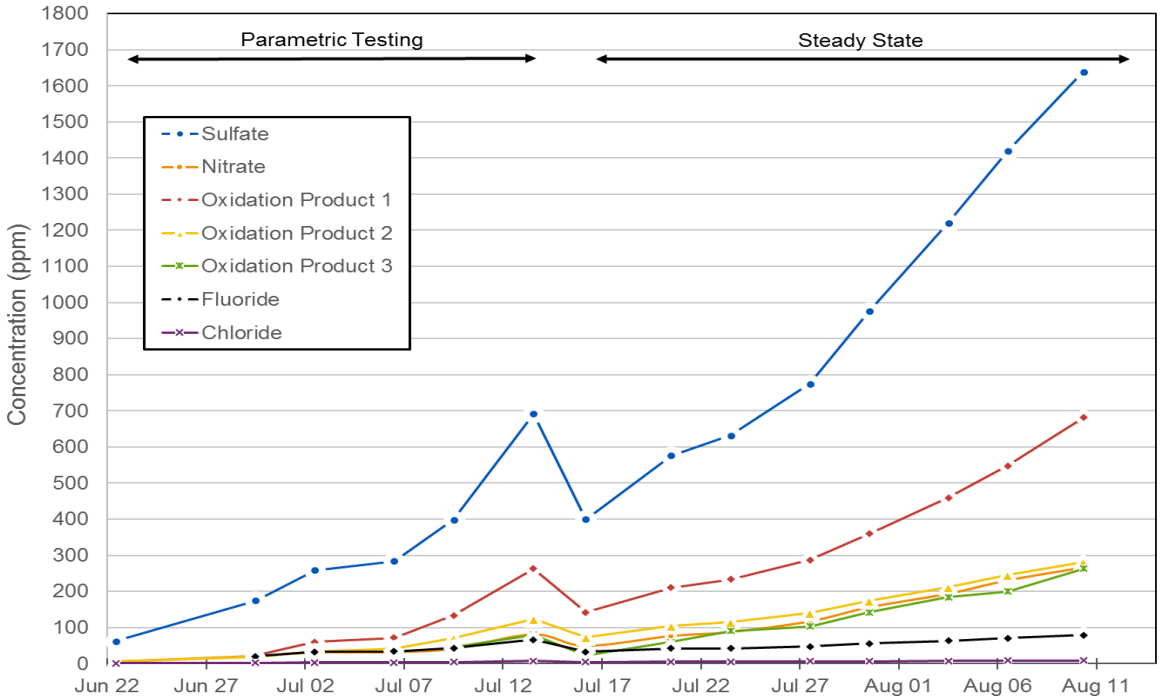


CO_2 Capture Performance

(>95% CO_2 captured throughout campaign)



Heat Stable Salt Accumulation



- High sulphate and nitrate due to SO_x and NO_x (aerosol inlet), resp.
- Low oxidation product concentrations even after 1,100 h
  - Solvent was never drained or reclaimed during test campaign

Metals and Corrosion

(Poster – Tyler Silverman)

- Process coupons show minimal impact to 304, 304L, or 316L under harsh conditions of regenerator for over 1,100 hours
  - As expected the carbon steel coupon shows corrosion
- Better Stainless Steel compatibility than MEA
- Key Compounds (SS Corrosion)
  - Chromium
  - Nickel
  - Silicon (pending results)
  - *Iron (fly-ash can convolute data)*
- ION solvent accumulates significantly less metal ions than MEA

Corrosion Coupons from Regenerator

ION CAMPAIGN AT NCCC - SUMMARY

Fundamental Risks Addressed

Performance

ION Campaign at NCCC Summary

Fundamental Risks Addressed

- Solvent Degradation (& loss)
  - No new compounds identified during NCCC testing
  - ProTreat® confirmed to be representative of actual solvent loss
- Corrosivity of Solvent
  - Excellent performance observed, longer evaluation periods needed
- Water Balance
  - Controlled throughout NCCC testing

ION Campaign at NCCC Summary

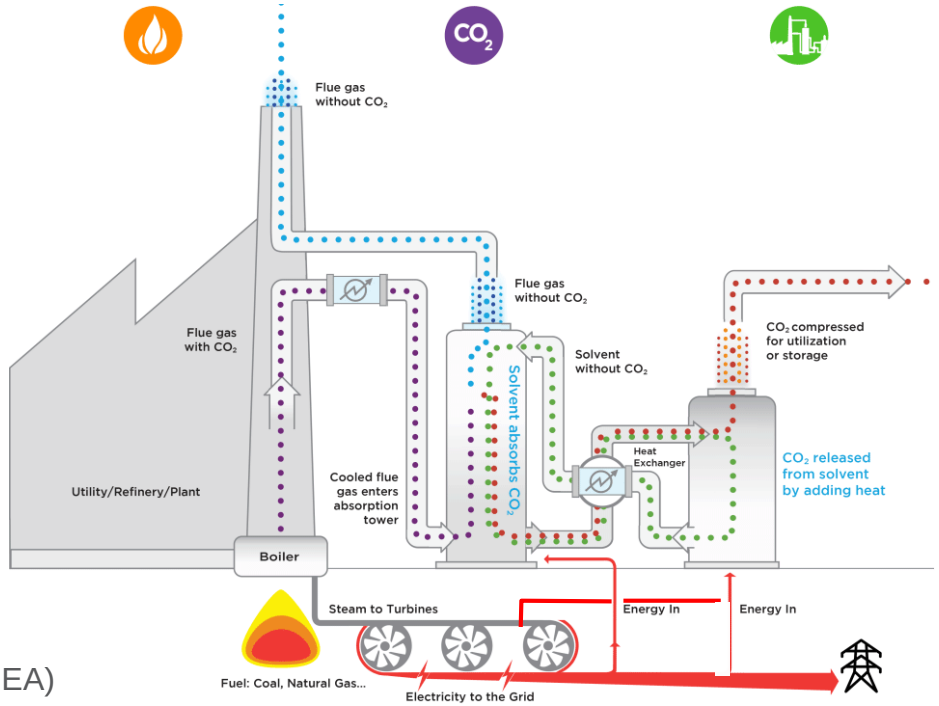
Performance

- >1,100 hours testing in Real Process Environment (TRL-6) within capture plant designed for MEA
- Achieved >98% capture of CO_2 throughout campaign
  - 1,600 BTU/lb CO_2 at Steady State
- Validated ProTreat® model of ION Technology
  - 1,090 BTU/lb CO_2 (2.5 MJ/kg CO_2) in ION Basic Design Case
- Evaluated L/G: 2.0 – 3.5 (higher than ION-optimum)
  - Control of absorber temperature profile
  - Maintained water balance and capture targets
- Solvent loss evaluated for parametric & steady state conditions
- Mass balances within 5%

ION Technology

- **Solvent Based Technology**
- **Reduced CAPEX**
  - Smaller Columns, HXs and Footprint
- **Reduced OPEX**
  - Lower Energy Requirements
  - Less Maintenance
  - Lower emissions
- **Lower Parasitic Load**
- **Scalability**
  - Established Engineering Process

- **Basis of Performance**
  - < 1,090 Btu/lbCO_2 captured (2.5 MJ/kg)
  - Fast kinetics (on par or faster than MEA)
  - Working capacity (higher than MEA)
  - Low heat capacity (much lower than MEA)
  - Low tendency for corrosion (much lower than MEA)



2016 TECHNO-ECONOMIC ASSESSMENT

2016 DOE TEA Methodology

- TEA based on Bituminous Baselines Study (BBS) Case 12 (supercritical pulverized coal plant) with Fluor's Econamine FG Plus℠ carbon capture technology

- TEA was performed to develop a 550MW$_{net}$ greenfield, super critical, coal power plant coupled with a post-combustion CO_2 capture (PCC) system

- ION CO_2 Capture system:
  - Designed to achieve 90% capture
  - Produces a CO_2 product purity of ≥ 99% at 2,215 psia (15.3MPa)

- DOE NETL requires the report to be published using guidance:
  "*Cost and Performance Baseline for Fossil Energy Plants - Volume 1: Bituminous Coal and Natural Gas to Electricity (Rev 2, November 2010),"* aka BBS with economic updates from the report "*Updated Costs (June 2011 Basis) for Selected Bituminous Baseline Cases*"

2016 TEA Conclusions

- ION 2016 TEA was performed by Sargent & Lundy using ION's ProTreat® simulations, which model was validated by NCCC test campaign

- Performance Results:
  - 38% incremental reduction in CAPEX
  - 28% incremental reduction in OPEX
  - 32% decrease in ICOE
  - Cost of Capture: \$39-\$45 / tCO_2

Outlook: ION Campaign at TCM

Acknowledgement and Disclaimer

Acknowledgement

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